

Hydrogen-Oxygen PEM Regenerative Fuel Cell at NASA Glenn Research Center

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The NASA Glenn Research Center has constructed a closed-cycle hydrogen-oxygen PEM regenerative fuel cell (RFC) to explore its potential use as an energy storage device for a high altitude solar electric aircraft.

Built up over the last 2 years from specialized hardware and off the shelf components the Glenn RFC is a complete "brassboard" energy storage system which includes all the equipment required to (1) absorb electrical power from an outside source and store it as pressurized hydrogen and oxygen and (2) make electrical power from the stored gases, saving the product water for re-use during the next cycle.

It consists of a dedicated hydrogen-oxygen fuel cell stack and an electrolyzer stack, the interconnecting plumbing and valves, cooling pumps, water transfer pumps, gas recirculation pumps, phase separators, storage tanks for oxygen (O₂) and hydrogen (H₂), heat exchangers, isolation valves, pressure regulators, nitrogen purge provisions, instrumentation, and other components. Its specific developmental functions include

- (1) Test fuel cells and fuel cell components under repeated closed-cycle operation (nothing escapes; everything is used over and over again).
- (2) Simulate diurnal charge-discharge cycles
- (3) Observe long-term system performance and identify degradation and loss mechanisms.
- (4) Develop safe and convenient operation and control strategies leading to the successful development of mission-capable, flight-weight RFC's

The developmental goals are to demonstrate repeatable operation at rated power and energy storage capacity (i.e. 10's of charge-discharge cycles with no intervention required, no observable degradation and minimal reactant losses), round trip efficiencies exceeding than 50

pct, and to utilize lessons learned towards the design and development of a flightweight closed-cycle hydrogen-oxygen PEM RFC (specific energy density better than 600 W-hr/kg.).

This paper reports the system level performance achieved to date, including but not limited to

- 1.) number of repeated day-night cycles w/o mishap
- 2.) steady state power delivered over one discharge cycle
- 2.) actual round trip efficiency recorded
- 3.) reactant losses observed over 10 day-nite cycles

A 600 Whr/kg closed cycle RFC would be the highest storage capacity and lowest weight of any non-nuclear energy storage device. Realization of the system level goal can lead to the successful demonstration of a mission capable unmanned solar electric aircraft with potentially unlimited endurance. In addition to solar aircraft the closed cycle RFC is also applicable to a wide variety of space and planetary surface missions: hence, there is widespread interest throughout NASA to bring this technology to a flight demonstration.